

# **Data Enhanced Modeling of Sea and Swell on The Continental Shelf**

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Document #: N0001498WR30002

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Document #: N0001498WX30037

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Grant #: N0014-98-1-0019

## **LONG-TERM GOAL**

Our long-term goal is to contribute to the accurate prediction of surface gravity wave generation, propagation, and dissipation in coastal regions through the combined use of measurements and models.

## **OBJECTIVES**

Our primary objectives are to develop robust wave data assimilation and higher order wave propagation schemes for the Delft Hydraulics shallow water SWAN model. In the process of developing the wave data assimilation methods, the types of wave data (e.g. remotely sensed or in situ) and measurement locations (e.g. at the offshore model boundary or in the nearshore) that provide the most useful constraints on model predictions will be identified.

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE <b>1998</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-1998 to 00-00-1998</b>	
4. TITLE AND SUBTITLE <b>Data Enhanced Modeling of Sea and Swell on The Continental Shelf</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Naval Postgraduate School, Department of Oceanography, Code OC/He, Monterey, CA, 93943</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>See also ADM002252.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>3</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

## APPROACH

Our approach for improving the SWAN wave propagation scheme (first-order, upwind) is to explore a variety of higher order schemes that have been developed or proposed by others in related research fields. The primary shortcoming of the first-order scheme has been the excessive directional diffusion of wave energy as it progresses through the numerical domain. Therefore, one of the principal standards for judging the higher order schemes is their stability in this regard. The most promising higher order scheme will be implemented in the SWAM model. Model validated will include several historical data sets from the U.S. East and West coasts to insure its applicability to a wide range of environmental conditions and geographic settings.

Our approach to adding data assimilation capabilities to the SWAN model is to: 1. identify the types of wave measurements available on or near the continental shelf, 2. relate these measurements to the SWAN model's spectral output with as few additional assumptions as possible, and 3. assimilate this information using methods that are computationally feasible for use in future operational products. An operational shallow water swell prediction model for the California coast, initialized with deep water forecast spectra from the FNMOC global WAM model, will be used as a baseline for assessing the benefits of different data assimilation strategies.

## WORK COMPLETED

Numerous potential higher order propagation schemes were tested by propagating a Gaussian waveform across uniform bathymetry. An algorithm developed by G. Stelling at Delft Hydraulics was deemed the most promising and has been incorporated into an experimental version of the SWAN model for testing over more realistic bathymetries.

Real-time output from the U.S. Navy's global wave forecast model (FNMOC WAM) was integrated with a linear, spectral refraction-diffraction (RD) model to make operational shallow water wave forecasts for the California coastline (Figure 1). The RD model does not include local generation of waves on the shelf, but has been shown to accurately predict swell conditions across a narrow shelf. The coastal forecasts are ongoing and will be compared to experimental versions of the SWAN model.

A wave data assimilation workshop was held at Scripps Institution of Oceanography in September, 1988. The workshop was highlighted by invited European speakers who are active in related research areas. A much better understanding of how to relate SAR and LIDAR information to SWAN output emerged from the meeting. In addition, it was concluded that wave data assimilation at the model boundary is likely to be the highest priority in practical applications, and that this should be the focus of our initial assimilation efforts. Finally, the coastal region around Pt. Conception, CA, was chosen as the first field validation site owing to the narrow shelf (smaller bathymetry grid), potential availability of high resolution wind fields from COAMPS, and the relatively large number of in situ measurements in this area.

[Edit: Figure 1 would not translate]

Figure 1. 36 hour forecast of wave heights on the continental shelf off San Francisco, CA, for a large El Nino winter storm event February 5-6, 1998. The shelf wave model is initialized with deep water

forecast spectra from the FNMOC global WAM model. The event was unusual in the severity of the waves approaching the coast from the south, and the forecast was used to place coastal residents on south-facing beaches on a heightened alert.

## **RESULTS**

Preliminary simulations with the higher order wave propagation schemes over realistic shallow water bathymetries indicate a significant sensitivity to inhomogeneous offshore boundary conditions. In addition, bottom dissipation appears to be particularly strong in the present SWAN model formulation. This latter finding will be explored further using a cross-shelf transect of wave measurements collected off North Carolina during Duck94.

The experimental integration of the FNMOC WAM model with the RD model has produced surprisingly useful results at swell frequencies. The more ad hoc treatment of local seas (no additional generation on the shelf) performs poorly in areas partially sheltered by offshore islands.

## **IMPACT/APPLICATION**

The data assimilation workshop was a very important beginning to the integration of shallow water remotely sensed data into wave models. While some details remained to be worked out, the framework for developing and testing assimilation methods has been put in place.

The modest success of the FNMOC WAM - RD coastal forecasts is encouraging, with the implication that accurate SWAN model predictions over large coastal regions are possible if the numerical propagation errors can be minimized with a higher order scheme.

## **TRANSITIONS**

As part of the FNMOC WAM - RD coastal forecast model effort, a method has been developed to extract very long range swell forecasts from FNMOC WAM model output. The long range model is being passed to Larry Hsu at NRL for development into an operational tool as part of the SPAWAR program.

Real-time, experimental 3 day forecasts for the California coast are being disseminated on the internet through the Coastal Data Information Program at Scripps Institution of Oceanography.

## **RELATED PROJECTS**

1. Shoaling Waves DRI field experiment.
2. SandyDuck field experiment
3. Duck94 field experiment
4. The Coastal Data Information Program, USACE and CA Dept. of Boating and Waterways
5. MMS Study: Modeling Waves in the Santa Barbara Channel
6. Joint work with Paul Wittmann, FNMOC-Monterey
7. Joint SPAWAR work with Larry Hsu, NRL-Stennis

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